

Radiation Awareness for Endovascular Abdominal Aortic Aneurysm Repair in the Hybrid Operating Room. Part I: An Instant Patient Risk Chart for Daily Practice. Quirina M. de Ruiter et al.

Supplemental Table S1. Methodology for Correcting Patient Radiation Dose Rates for the Prediction Models.

	Raw Data	Calculation	Baseline	Maximum	Step Size in the Models
Fluoroscopy Protocol	Low, medium, normal	$DR = FT_{run} / Dose_{run}$	Low	Normal	1 step
DSA Protocols	2 fps	$DR = (Fr_{run} / Dose_{run}) * 2$	2 fps	3 fps	1 step
	3 fps	$DR = (Fr_{run} / Dose_{run}) * 3$			
Rotation, deg	-90 to 0 to +90	Absolute 0-90	0 (AP)	90 (LAO or RAO)	30 LAO or RAO
Angulation, deg	-35 to 0 to +35	Absolute 0-40	0 (AP)	90 (cranial or caudal)	30
BMI, kg/m ²	—	—	18	42	5 points of BMI
Field size, cm ²	Top shutter – left shutter	Detector field size=1450–field size	1450 (no collimation or magnification and maximum SID)	0 (maximum collimation or magnification)	-300 to 0 cm ²
Air gap, cm	SID ranges from 90 to 120	Air gap=120–SID	120 (maximum SID)	90 (minimum SID)	-5 to 90 cm (minimum air gap)

Abbreviations: AP, anteroposterior; BMI, body mass index; DR, dose rate; DSA, Digital subtraction angiography; Fr, frames; FT, fluoroscopy time; LAO, left anterior oblique; RAO, right anterior oblique; SID, source-to-image distance.

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Supplemental Table S2. Overall Radiation Dose Rates (DR_{AK} and DR_{DAP}) for Fluoroscopy and Digital Subtraction Angiography Without Correcting for Other Factors.^a

	Fluoroscopy Protocol ^b			DSA Protocol ^b		
	Runs	DR _{AK} , mGy/s	DR _{DAP} , mGy ² /s	Runs	DR _{AK} , mGy/s	DR _{DAP} , mGy ² /s
Rotation, deg						
AP (0–15)	10623 (62.9)	0.25±0.2	62±51	441 (2.6)	4.2±3	1001±726
Oblique 15–30	2895 (17.1)	0.45±0.35	89±84	242 (1.4)	7.3±5.4	1390±896
Oblique 30–45	997 (5.9)	0.44±0.27	91±84	73 (0.4)	9.2±4.4	1944±1128
Oblique 45–60	193 (1.1)	0.88±0.56	130±105	15 (0.1)	18.6±5.1	3895±1933
Oblique 60–75	326 (1.9)	0.85±0.39	138±88	20 (0.1)	14.4±2.3	2764±1163
Lateral (75–90)	997 (5.9)	0.75±0.42	114±81	67 (0.4)	14.6±5.6	2403±1218
Angulation, deg						
AP (0–15)	13553 (80.2)	0.34±0.32	6.8±5.8	13553 (80.2)	69±60	1244±946
Oblique 15–30	2367 (14)	0.37±0.29	6.4±4.4	2367 (14)	101±89	1668±1149
Oblique 30–45	111 (0.7)	0.61±0.46	11.6±5.1	111 (0.7)	153±130	3005±1997
BMI, kg/m ²						
<20	245 (1.5)	0.1±0.05	1.5±0.4	245 (1.5)	23±12	343±102
20–25	6543 (38.7)	0.28±0.25	5.3±4.4	6543 (38.7)	58±48	1133±891
25–30	6319 (37.4)	0.36±0.31	7.1±5.3	6319 (37.4)	76±71	1414±1052
30–35	2518 (14.9)	0.46±0.35	10.2±6.8	2518 (14.9)	109±81	2161±1289
>35	406 (2.4)	0.83±0.48	13.6±5.9	406 (2.4)	125±87	2044±729
Field size, cm ²						
1200–1400	679 (4)	0.13±0.12	1.9±1.1	679 (4)	67±63	933±562
1000–1200	1816 (10.8)	0.18±0.15	3±2.2	1816 (10.8)	81±64	1278±778
800–1000	2262 (13.4)	0.27±0.25	4.7±4	2262 (13.4)	99±92	1628±1399
600–800	3247 (19.2)	0.31±0.27	6±4.5	3247 (19.2)	88±73	1656±1120

400–600	3195 (18.9)	0.34±0.3	7.4±5.6	3195 (18.9)	72±64	1562±1216
200–400	3514 (20.8)	0.46±0.35	9.1±5.4	3514 (20.8)	59±45	1126±655
0–200	1318 (7.8)	0.63±0.38	13.4±6.3	1318 (7.8)	38±27	734±453
SID, cm						
115–120				245 (1.5)	23±12	343±102
110–115				6543 (38.7)	58±48	1133±891
105–110				6319 (37.4)	76±71	1414±1052
100–105				2518 (14.9)	109±81	2161±1289
90–100				406 (2.4)	125±87	2044±729

Abbreviations: AP, anteroposterior; BMI, body mass index; DSA, digital subtraction angiography; SID, source-to-image distance.

^a Rotation, angulation, BMI, field size, and SID.

^b Continuous data are presented as the means ± standard deviation; categorical data are given as the counts (percentage).

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Supplemental Table S3. Overall Radiation Dose Rates for Air Kerma (DR_{AK}) for Fluoroscopy and Digital Subtraction Angiography With Correction for Other Factors.^a

	Fluoroscopy Protocol ^b						DSA Protocol ^b			
	Low		Medium		Normal		2 fps		3 fps	
Rotation, deg	Runs	DR _{AK} , mGy/s	Runs	DR _{AK} , mGy/s	Runs	DR _{AK} , mGy/s	Runs	DR _{AK} , mGy/s	Runs	DR _{AK} , mGy/s
AP (0–15)	6649 (39.4)	0.13±0.05	2464 (14.6)	0.32±0.1	1510 (8.9)	0.63±0.19	320 (1.9)	3.6±2.4	121 (0.7)	5.7±3.9
Oblique 15–30	1259 (7.5)	0.19±0.06	885 (5.2)	0.41±0.12	751 (4.4)	0.95±0.3	153 (0.9)	6±3.8	89 (0.5)	9.7±6.8
Oblique 30–45	484 (2.9)	0.23±0.05	381 (2.3)	0.52±0.12	132 (0.8)	0.98±0.24	56 (0.3)	8.4±3.5	17 (0.1)	11.6±5.9
Oblique 45–60	52 (0.3)	0.27±0.05	79 (0.5)	0.68±0.07	62 (0.4)	1.64±0.09	5 (0)	14.2±4.2	10 (0.1)	20.8±4
Oblique 60–75	42 (0.2)	0.28±0.02	201 (1.2)	0.72±0.06	83 (0.5)	1.44±0.2	15 (0.1)	13.2±1	5 (0)	17.9±1.1
Lateral (75–90)	277 (1.6)	0.28±0.03	513 (3)	0.73±0.07	207 (1.2)	1.45±0.2	50 (0.3)	12.2±3.8	17 (0.1)	21.5±4.5
Angulation, deg										
AP (0–15)	7312 (43.3)	0.14±0.06	4024 (23.8)	0.42±0.19	2217 (13.1)	0.84±0.38	440 (2.6)	5.8±4.4	169 (1)	9.6±7.8
Oblique 15–30	1405 (8.3)	0.2±0.06	454 (2.7)	0.4±0.14	508 (3)	0.82±0.26	149 (0.9)	5.2±3.3	84 (0.5)	8.5±5.3
Oblique 30–45	46 (0.3)	0.24±0.04	45 (0.3)	0.61±0.11	20 (0.1)	1.47±0.29	10 (0.1)	10.4±4.7	6 (0)	13.7±5.4
BMI, kg/m ²										
<20	217 (1.3)	0.09±0.02	28 (0.2)	0.23±0			10 (0.1)	1.4±0.4	4 (0)	1.6±0.4
20–25	4139 (24.5)	0.15±0.06	1787 (10.6)	0.41±0.2	617 (3.7)	0.73±0.36	243 (1.4)	5.1±4.3	111 (0.7)	5.6±4.6
25–30	3282 (19.4)	0.15±0.06	1931 (11.4)	0.42±0.17	1106 (6.5)	0.84±0.34	279 (1.7)	6±4	80 (0.5)	10.7±7.3
30–35	1040 (6.2)	0.18±0.06	655 (3.9)	0.44±0.16	823 (4.9)	0.84±0.34	50 (0.3)	5.4±3.3	61 (0.4)	14±6.4
>35	85 (0.5)	0.2±0.04	122 (0.7)	0.59±0.14	199 (1.2)	1.26±0.27	17 (0.1)	11.9±4.4	3 (0)	22.7±5.4
Field size, cm ²										
1200–1400	556 (3.3)	0.09±0.03	79 (0.5)	0.16±0.04	44 (0.3)	0.55±0.13	33 (0.2)	1.9±1.2	6 (0)	2±0.8
1000–1200	1335 (7.9)	0.11±0.03	292 (1.7)	0.25±0.08	189 (1.1)	0.53±0.17	62 (0.4)	2.5±1.7	14 (0.1)	5±3.1

800–1000	1365 (8.1)	0.13±0.05	498 (2.9)	0.33±0.12	399 (2.4)	0.69±0.29	83 (0.5)	3.4±2.4	50 (0.3)	6.7±5.2
600–800	1951 (11.6)	0.16±0.06	645 (3.8)	0.35±0.17	651 (3.9)	0.74±0.29	118 (0.7)	5.1±3.5	84 (0.5)	7.4±5.4
400–600	1712 (10.1)	0.17±0.06	937 (5.5)	0.36±0.16	546 (3.2)	0.84±0.35	115 (0.7)	5.7±4	57 (0.3)	10.8±6.7
200–400	1592 (9.4)	0.2±0.06	1299 (7.7)	0.52±0.17	623 (3.7)	0.99±0.38	142 (0.8)	8.3±4.3	31 (0.2)	12.8±8.1
0–200	252 (1.5)	0.21±0.04	773 (4.6)	0.54±0.12	293 (1.7)	1.23±0.25	46 (0.3)	10.6±3.5	17 (0.1)	20.9±5.9
SID, cm										
115–120							72 (0.4)	10.9±4.4	27 (0.2)	17.9±6.2
110–115							85 (0.5)	7.7±4.4	31 (0.2)	14.9±7.4
105–110							89 (0.5)	5.6±3.6	42 (0.2)	8.9±4.8
100–105							213 (1.3)	4.5±3.2	92 (0.5)	8.5±6.5
90–100							140 (0.8)	3.7±2.9	67 (0.4)	4.6±3.6

Abbreviations: AP, anteroposterior; BMI, body mass index; DSA, digital subtraction angiography; fps, frames per second; SID, source-to-image distance.

^a Rotation, angulation, BMI, field size, and SID.

^b Continuous data are presented as the means ± standard deviation; categorical data are given as the counts (percentage).

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Supplemental Table S4. Overall Radiation Dose Rates for Dose Area Product (DR_{DAP}) for Fluoroscopy and Digital Subtraction Angiography With Correction for Other Factors.^a

	Protocol Fluoroscopy						Protocol DSA			
	Low		Medium		Normal		2 fps		3 fps	
	Runs	DR _{DAP} , mGycm ² /s	Runs	DR _{DAP} , mGycm ² /s	Runs	DR _{DAP} , mGycm ² /s	Runs	DR _{DAP} , mGycm ² /s	Runs	DR _{DAP} , mGycm ² /s
Rotation, deg										
AP (0–15)	6649 (39.4)	38±15	2464 (14.6)	67±31	1510 (8.9)	156±67	320 (1.9)	827±469	121 (0.7)	1460±1026
Oblique 15–30	1259 (7.5)	42±17	885 (5.2)	71±40	751 (4.4)	188±104	153 (0.9)	1241±912	89 (0.5)	1645±813
Oblique 30–45	484 (2.9)	55±22	381 (2.3)	82±57	132 (0.8)	248±114	56 (0.3)	1730±934	17 (0.1)	2647±1430
Oblique 45–60	52 (0.3)	62±19	79 (0.5)	123±79	62 (0.4)	195±135	5 (0)	2295±774	10 (0.1)	4694±1847
Oblique 60–75	42 (0.2)	39±16	201 (1.2)	112±47	83 (0.5)	252±75	15 (0.1)	2217±640	5 (0)	4406±704
Lateral (75–90)	277 (1.6)	54±27	513 (3)	103±50	207 (1.2)	222±90	50 (0.3)	1939±788	17 (0.1)	3768±1250
Angulation, deg										
AP (0–15)	7312 (43.3)	39±17	4024 (23.8)	71±38	2217 (13.1)	165±80	440 (2.6)	1056±733	169 (1)	1734±1224
Oblique 15–30	1405 (8.3)	50±17	454 (2.7)	119±50	508 (3)	225±104	149 (0.9)	1386±888	84 (0.5)	2168±1374
Oblique 30–45	46 (0.3)	52±19	45 (0.3)	148±39	20 (0.1)	396±78	10 (0.1)	2222±1291	6 (0)	4310±2386
BMI, kg/m ²										
<20	217 (1.3)	20±8	28 (0.2)	48±1			10 (0.1)	344±83	4 (0)	340±155
20–25	4139 (24.5)	38±16	1787 (10.6)	72±42	617 (3.7)	153±72	243 (1.4)	962±689	111 (0.7)	1507±1140
25–30	3282 (19.4)	41±17	1931 (11.4)	75±42	1106 (6.5)	179±103	279 (1.7)	1244±851	80 (0.5)	2008±1416
30–35	1040 (6.2)	52±16	655 (3.9)	92±43	823 (4.9)	194±81	50 (0.3)	1509±818	61 (0.4)	2695±1361
>35	85 (0.5)	40±22	122 (0.7)	86±42	199 (1.2)	186±79	17 (0.1)	1967±657	3 (0)	2479±1119
Field size, cm ²										
1200–1400	556 (3.3)	47±14	79 (0.5)	84±20	44 (0.3)	285±69	33 (0.2)	947±608	6 (0)	855±171
1000–1200	1335 (7.9)	53±13	292 (1.7)	111±29	189 (1.1)	232±81	62 (0.4)	1105±716	14 (0.1)	2046±557
800–1000	1365 (8.1)	47±19	498 (2.9)	118±46	399 (2.4)	256±100	83 (0.5)	1243±917	50 (0.3)	2267±1789

600–800	1951 (11.6)	46±15	645 (3.8)	101±48	651 (3.9)	202±71	118 (0.7)	1465±990	84 (0.5)	1925±1236
400–600	1712 (10.1)	35±12	937 (5.5)	76±36	546 (3.2)	178±78	115 (0.7)	1226±855	57 (0.3)	2240±1526
200–400	1592 (9.4)	26±9	1299 (7.7)	66±24	623 (3.7)	129±44	142 (0.8)	1054±574	31 (0.2)	1453±882
0–200	252 (1.5)	14±5	773 (4.6)	32±15	293 (1.7)	72±32	46 (0.3)	580±287	17 (0.1)	1151±556
SID, cm										
115–120							72 (0.4)	1841±804	27 (0.2)	3468±1277
110–115							85 (0.5)	1657±1070	31 (0.2)	3172±1934
105–110							89 (0.5)	1183±740	42 (0.2)	1763±689
100–105							213 (1.3)	910±552	92 (0.5)	1722±1119
90–100							140 (0.8)	862±636	67 (0.4)	1144±739

Abbreviations: AP, anteroposterior; BMI, body mass index; DSA, digital subtraction angiography; fps, frames per second; SID, source-to-image distance.

^a Rotation, angulation, BMI, field size, and SID.

^b Continuous data are presented as the means ± standard deviation; categorical data are given as the counts (percentage).

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Supplemental Table S5. Univariate Outcomes.^a

Dose Rate Model	Air Kerma	Dose Area Product
Fluoroscopy		
Protocol: low to medium	2.48 (2.45 to 2.52), p<0.001	1.78 (1.75 to 1.81), p<0.001
Protocol: low to normal	4.89 (4.81 to 4.99), p<0.001; 0.81	3.7 (3.61 to 3.79), p<0.001; 0.65
Rotation (+30 deg)	1.59 (1.57 to 1.61), p<0.001; 0.56	1.3 (1.29 to 1.32), p<0.001; 0.41
Angulation (+30 deg)	2.12 (2.04 to 2.21), p<0.001; 0.43	1.9 (1.83 to 1.98), p<0.001; 0.39
BMI (+5 points)	1.58 (1.36 to 1.83), p<0.001; 0.39	1.5 (1.33 to 1.72), p<0.001; 0.35
Irradiated field (−200 cm ²)	1.39 (1.37 to 1.4), p<0.001; 0.53	0.82 (0.81 to 0.83), p<0.001; 0.41
DSA		
Protocol: 2 fps to 3 fps	1.77 (1.6 to 1.97), p<0.001; 0.56	1.78 (1.61 to 1.97), p<0.001; 0.51
Rotation (+30 deg)	1.75 (1.68 to 1.82), p<0.001; 0.75	1.52 (1.46 to 1.58), p<0.001; 0.63
Angulation (+30 deg)	2.06 (1.76 to 2.44), p<0.001; 0.55	2.01 (1.72 to 2.32), p<0.001; 0.50
BMI (+5 points)	1.68 (1.42 to 1.96), p<0.001; 0.49	1.58 (1.38 to 1.78), p<0.001; 0.43
Irradiated field (−200 cm ²)	1.50 (1.45 to 1.56), p<0.001; 0.70	0.88 (0.85 to 0.92), p<0.001; 0.46
Air gap (−5 cm)	0.72 (0.7 to 0.74), p<0.001; 0.71	0.76 (0.74 to 0.78), p<0.001; 0.63

Abbreviations: BMI, body mass index; DSA, digital subtraction angiography;

^a Data are presented as the odds ratio (95% confidence interval), p value; coefficient of multiple determination.